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TERRAINS AND SOILS OF THE BASALTIC PLAINS OF FAR WESTERN VICTORIA

By Frank R. Gibbons
Soil Conservation Authority of Victoria

and Edmund D. Gill
National Museum of Victoria

Abstract

Nine land-systems covering 1200 square miles of the basaltic plains in SW. Victoria are described and their distribution shown. These land-systems are areas where there is a consistent pattern of various features of the natural environment—climate, parent material, topography, soils, and vegetation, and the description is in terms of these. The evidence for the age of the basalts of the various land-systems is discussed, particularly the significance of the residual weathering-formations and soils. The six patterns of soils and weathering-products suggest six periods of extrusion of basalt, each linked with one or more land-systems, the earliest having been in the Middle or Upper Pliocene and the latest in the Holocene. It is suggested that the approach could be applied to the rest of the basaltic plains.

Basis of Approach

The area discussed covers about 1200 square miles at the W. extremity of the basalt plains, about 13% of the total area of the plains. It lies in the SW. corner of Victoria, W. of Penshurst and S. of Cavendish. During surveys conducted there by the Soil Conservation Authority (Gibbons and Downes 1964 in press), different kinds of land were recognized, mapped, and described. Each is characterized by a consistent pattern of natural features such as topography, rocks, soils, and native vegetation. On the broad scale the patterns are called **land-systems**, and these form the basis of the following description of terrains and soils on basalt (Fig. 1).

Different land-systems have been derived from the same geological material, and this indicates that the land-systems have been subject to different conditions.

The present climate varies over the area from 25 in. to more than 36 in. average annual rainfall, with slight differences in the temperature régime. However, the climate of former periods may have differed from that of the present by much more than this range. Consequently, factors which may be responsible for the differences between the land-systems are the present climate, the time during which the basalt has been subject to the present climate, and the age of the basalt, which controls the former climatic régime(s) to which it has been subjected. One of us (F.R.G.) considers that some differences between the patterns, particularly between the Cobbobboonee land-system and the other land-systems, are the result of the present climatic differences. However, because the patterns are consistent within relatively sharp boundaries, and differ considerably from each other, it is believed that the last of the above-mentioned factors, namely the age of the basalt, is the most important. This conclusion is supported by the fact that widely-different times of extrusion can be proved in certain places.

Consequently, the areas of the various patterns are considered to indicate the areas of different flows or series of flows of basalt and the areas to which relative or absolute datings may be applied.

Nine land-systems associated with basalt have been recognized and mapped in the area of survey, and in the rest of this paper they are described and the evidence for their age is considered.

The Land-Systems and Their Features

Hamilton and Branxholme Land-Systems

Around Hamilton, and particularly to the S. of it, is a basaltic terrain that has been dissected to depths of 200 ft, thus exposing underlying sedimentary rocks. Areas where dissection has not reached these rocks have been mapped as the Hamilton land-system, and areas where these rocks have been widely exposed have been mapped as the Branxholme land-system.

On the highest parts of both these land-systems is a zone of kaolinitic weathering which may be over 30 ft thick. Where thickest, this zone has an upper strongly reddened and friable sub-zone, an intermediate mottled sub-zone, and a lower pallid sub-zone overlying the altered basalt. To this extent, it strongly resembles a classical profile of laterite (Prescott and Pendleton 1952), but nowhere in the basalt of these land-systems has there been found an indurated sub-zone characteristic of such a profile. Lateritic profiles with indurated sub-zones have been described for other areas in W. Victoria, as over the Dundas Tablelands (Stephens 1946) and at Camperdown (Gill 1953); the lateritic peneplain of the Dundas Tablelands is adjacent to the Hamilton land-system and at a lower level.

Soils in the Hamilton and Branxholme land-systems form a characteristic sequence with topography according to catenary position and to the rocks exposed by dissection. On the kaolinitic sub-zone, soils are either transitional krasnozems (**Hamilton** Series), red solodic soils (**Monivae** Series) or their intermediates. Middle and lower slopes on basalt dissected below the level of kaolinitic weatherings support brown solodic soils (**Normanby** family) which are usually gilgaied. Prairie soils or chernozems are in drainage lines, with peats in the wettest sites. In the Branxholme land-system, dissection below the level of the basalt exposes sandy sediments (e.g. around Macarthur) which support sandy solodic soils. Near Branxholme, Lower Cretaceous sediments give rise to prairie soils (**Whyte** Series). Kaolinitic nodules are common in soils in higher catenary positions but progressively less frequent in the lower sites, while ironstone nodules (buckshot) become increasingly frequent in the A2 horizons of lower sites.

Although the land-systems are now widely cleared of trees, there is evidence that the original vegetation was a dry sclerophyll forest dominated by swamp gum (*Eucalyptus ovata*) thinning to a savannah woodland and eventually to a grassland on heavier soils and lower sites. In drainage lines and on the peats were wet scrubs of tea-tree (*Melaleuca pubescens*) and most of this still remains. In the NW. part of this land-system, red gum (*Eucalyptus camaldulensis*) was mixed with swamp gum, or was dominant, forming savannah woodlands.

Cobbobboonee and Greenwald Land-Systems

NW. of Portland and W. of Heywood are areas of basalt which cover the W. parts of the Normanby Platform (Boutakoff 1952). This platform has Miocene sediments for its base and it shelves gently to the E. Most of the basalt has been mildly dissected by easterly flowing streams which expose the underlying sediments in a few places. Only where streams are cutting back into fault-scarps, such as the

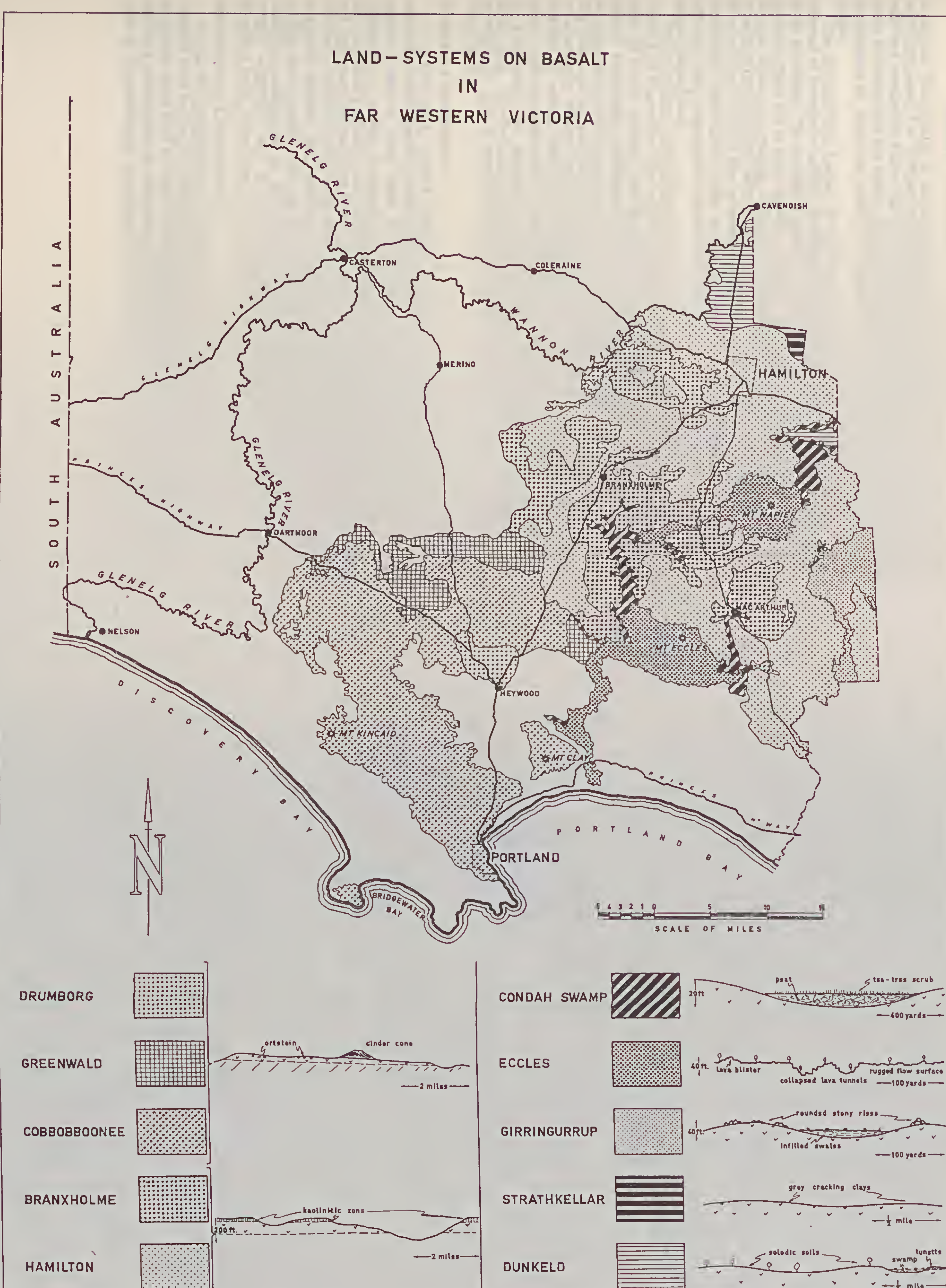

FIG. 1—Land-systems on basalt in far-W. Victoria. (Adapted from 'A Study of the land in South-western Victoria' by Gibbons and Downes 1964 in press.)

Kentbruck Fault-scarp, is the dissection deep or the exposure of underlying sediments extensive. The Cobbobboonee land-system is where the dissection has generally not penetrated below the basalt, while the Greenwald land-system is formed where the dissection has widely exposed the underlying sediments. There are a few cinder-cones of which the chief is Mt Eckersley, mapped as the Drumborg land-system.

The characteristic feature of the basalt on these land-systems is the common presence of ortstein, a nodular ironstone, which is found mostly on the upper parts of the landscape. The ortstein is pisolitic, rarely more than 2 ft thick, and may be a cemented mass but is more usually a loosely cemented and decomposing gravel in the soil. Under the ortstein, either unweathered basalt or, more often, a thin layer of mottled clay is found. Where there is no ortstein, there is usually an orange and red tenacious clay with fine, prominent and concentric mottles, and weak ironstone concretions. Mottled and pallid sub-zones which are deep, reddened and kaolinitic have not been encountered except along the cliffs at Portland; shallow dissection exposes fresh basalt.

The soils form a topographic sequence and are closely linked with the materials exposed by dissection. The ortstein, mottled clay, and fresh basalt give rise to two series of clayey podsolic soils (**Gorae** Series and **Cobbobboonee** Series) and transitional krasnozems (**Midwood** Series) respectively. **Gorae** Series has abundant buckshot gravel which has been derived probably from the ortstein; **Midwood** Series may have smaller quantities of gravel, probably formed at a later stage than that in the ortstein. Where Tertiary sediments are exposed, the soils on them are usually podzolic or solodic while, in drainage lines, prairie or meadow soils are formed. Much of the original timber remains. Because of the comparatively high rainfall, the 4 dominant tree species are messmate (*E. obliqua*), peppermint (*E. vitrea*), manna gum (*E. viminalis*), and swamp gum. The first named is restricted to the gravelly soils and is dominant thereon, while the last named is dominant in the wetter sites.

Dunkeld Land-System

S. of Cavendish, around Dunkeld, and between Penshurst and Hamilton are tracts of basaltic country which are little dissected and possess a few swamps with lunettes, scattered stony rises, and a broadly undulating topography. No deep weathering or massive ironstone has been observed. The chief feature is that the soils are mostly solodic soils (similar to the **Normanby** family), weakly gilgaied, and with abundant buckshot in the A2 and top of the B1 horizon. Less commonly, there are reddish chocolate soils which closely resemble the **Corangamite stony loam** of Leeper, Nicholls, and Wadham (1936) on stony rises, break-aways to streams, or flow edges; prairie soils are in depressions and on lunettes. Boulders of fresh basalt are common in the soil profile and on the surface. In the survey area, the original vegetation was an open savannah woodland of red gum with a low, spreading habit. Note: stony rises are ridges of basalt with very stony surfaces.

Strathkellar Land-System

To the NE. of Hamilton is basaltic country of similar topography to that of the Dunkeld land-system, but without swamps, and with very slight dissection. On the occasional stony rises the soils are **Corangamite stony loam,** and in the depressions are black prairie soils or chernozems; over the long gentle slopes which constitute most of the countryside are gilgaied brown prairie soils (dark greyish-brown cracking clays). Neither deep kaolinitic weathering, nor massive ortstein, nor abundant loose buckshot gravel have been observed, but small to moderate amounts of buckshot gravel (magnetic iron pisolites) are encountered in the surface horizons of the chief soils. The original vegetation over much of the land-system appears to have been a dry tussock grassland but, over some parts, swamp gum may have been lightly scattered.

This land-system and its characteristics were first recognized and mapped by G. T. Sibley Esq. to whom acknowledgement is made.

Girringurrup Land-System

Some stony rises have very rugged topography with unweathered angular blocks of basalt covering the surface, while others have a smoother and more gentle topography with rounded boulders partly weathered and more buried in soil. Rises of the latter type are associated with Mt Rouse and extend southwards in the direction of Port Fairy, being bounded on the W. by the Eumerella R. The difference in height between rise and contiguous hollow varies up to 40 ft, while the distance between rises varies from 50 ft to a few hundred yards. These stony rises constitute the Girringurrup land-system.

The pattern of soils is a simple catena. On the rises are thin reddish chocolate soils (**Corangamite stony loam**) with abundant rounded basalt boulders half buried in the soil and with onion weathering. These soils become darker further down the sides of the rises until, in the swales, they are black, heavy and cracking, sometimes with free carbonate and usually gilgaied; they may be regarded as prairie soils or chernozems, and resemble the **Mooleric clay** of Leeper, Nicholls, and Wadham (ibid.). The whole catena is part of one described by those authors. No evidence of deep weathering, massive ortstein, nor buckshot has been encountered, as in the previous land-systems, nor evidence of stream-dissection.

The land-system is generally treeless now, but the original parish plan of Tallangoork, compiled in 1862, gives descriptions which can be interpreted to mean that the vegetation was a sparse savannah woodland of manna gum and blackwood (*Acacia melanoxylon*) or lightwood (*A. implexa*) on the rises, with a wet tussock grassland of snow-grass (*Poa australis*) in the swales.

Eccles Land-System

Surrounding Mt Napier, and covering a large area to the W. of Mt Eccles, are stony rises mapped as the Eccles land-system.

Large, angular and almost unweathered boulders cover the surface. In places the topography is very rugged, with sudden rises and with precipitously-sided hollows up to 30 ft deep and 100 ft across. In both areas of the land-system there are steep-sided scoria cones up to 350 ft high, with some tuff and ropey lava, while layers of diatomite from a few inches to 7 ft thick are found in basins of former lakes and around existing lakes.

The lithology of the stony rises varies. At one extreme is moderately-vesicular basalt with discontinuous vesicles having walls over 10 mm thick as a rule; the boulders are big, solid, and closely packed. At the other extreme is highly-vesicular scoriaceous basalt with continuous vesicles having thin walls usually less than 5 mm thick and often less than 2 mm. Boulders are commonly only 6 to 9 in. in diameter, jagged, and poorly packed. These two groups tend to be mutually exclusive, suggesting two distinct volcanic products.

Two similar but distinguishable types of soil, brown earths, are referable to these two rock types, the **Napier stony loam** and the **Dunmore organic loam** respectively. The **Dunmore organic loam** is found also on the steep sides of hollows or lava blisters. Both soils have unusually high levels of exchangeable calcium, potassium, and phosphorus, probably because of lack of leaching. This is true of the **Dunmore organic loam** even more than of the **Napier stony loam** and the difference is doubtless a result of the more rapid weathering of the more vesicular rocks, or else the input of drainage waters highly-charged with metallic cations from weathering basalt above. The only other soils in this land-system are brown-earths on scoria cones and the deposits of diatomite.

Throughout the land-system, the original vegetation was a tall woodland of manna gum with occasional blackwood and wild cherry (*Exocarpus cupressiformis*), with an understorey of snow-grass. The stands on the shallow phase of the **Napier stony loam** are more open. As a result of fires, bracken now dominates the understorey.

CONDAH SWAMP LAND-SYSTEM

On any of the abovementioned land-systems, the blocking of the natural drainage, such as by lava flows, has resulted in the development of swamps and alluvial flats. These frequently support wet scrubs of tea-tree which, in turn, have produced carr-peats or peaty prairie soils and peaty meadow soils. Such areas have been mapped as the Condah Swamp land-system after the chief example; others are Buckley's Swamp, L. Gorrie Swamp and Homerton Swamp.

The Ages of the Land-Surfaces and Basalts

Nine different land-systems have been described which are all developed on basalt. The differences are not of equal degree—e.g. the difference between Hamilton and Branxholme land-systems on the one hand, and the Cobbobboonee and Greenwald land-systems on the other, is much greater than the difference between the Girringurrup and the Eccles land-systems. Also, while the first eight land-systems are developed directly on basalt, the Condah Swamp land-system is developed on materials now accumulating on the basalt, but it is included to complete the picture.

The weathering of the parent material in the land-systems developed directly on basalt differs in both kind and degree. The basalt of Girringurrup and Eccles land-systems may have been weathered under climates similar to that prevailing now. The Hamilton and Branxholme land-systems, however, present characteristics which could not be formed under the present type of climate, and so it may be inferred that some of the land-surfaces and all of the basalts in those land-systems are of some antiquity.

It is important to discriminate what is being dated. Different land-surfaces may have been formed progressively on any one basalt and the age of the land-surface, as indicated by the soil, is not necessarily the age of the basalt. It is necessary, therefore, to consider each land-system both as a whole and as a series of lesser land-surfaces.

HAMILTON AND BRANXHOLME LAND-SYSTEMS

The age of the basalt can be determined 4 miles W. of Hamilton. There, Grange Burn has cut through the lava to an underlying marine bed of Kalimnan (Lower Pliocene) age, in which a palaeosol has been developed (Gill 1955, 1957). In this fossil soil are preserved stumps of Celery Top Pine (*Phyllocladus*) which is now limited to Tasmania and parts of New Zealand, and a tooth of a cuscus possum which is now limited to Cape York and New Guinea. The climate during Kalimnan times was warmer than at present, as shown by the foraminifera and other fossils of the Kalimnan beds, and the climate of post-Kalimnan times was wetter and warmer than at present, as shown by the *Phyllocladus* and cuscus respectively. The local volcanoes began to be active during Kalimnan times, as is demonstrated by the presence of tuff in the Kalimnan beds at Muddy Ck nearby (Gill 1957a). Tuff also overlies those beds, and is present in the palaeosol under the basalt at Grange Burn. Thus, a great deal of time did not pass between the deposition of the Kalimnan beds, their emergence from the sea-floor, and the extrusion of the basalt. On this basis, the basalt may be dated as Middle Pliocene, and was extruded when the climate was warmer and wetter than at present.

This conclusion is supported by the presence of the kaolinitic zone on the upper parts of the basalt. One of us (E.D.G.) has studied the presence of laterite (*sensu strictu*) in Victoria and has found that laterite, which is a terrestrial formation, has developed on dateable marine beds as young as uppermost Miocene (Cheltenhamian) but nowhere on Kalimnan marine beds, which are mutually exclusive in distribution with lateritized areas. It is inferred, therefore, that, in Victoria, lateritization occurred during Lower Pliocene times. Furthermore, it has been noted that, in the Upper Pliocene (using a twofold division of that period), the waning lateritizing conditions have deeply leached and reddened the sediments but have not produced a proper lateritic profile with an indurated sub-zone. It was apparently during this time that the deeply leached kaolinitic profile found on the basalts of the Hamilton-Branxholme landscape was produced.

If the age of both the basalt and the kaolinitic zone be Pliocene, then it is to be anticipated that the palaeosol will have been modified at the surface by Quaternary climates, and also that different soils will be found in the valleys cut into this landscape. Both these, in fact, have happened.

The basalt within the area of the Hamilton and Branxholme land-systems, therefore, is considered to have been extruded during Middle Pliocene or Upper Pliocene times, although areas of later flows, too small to map, are known to be included also.

Cobbobboonee and Greenwald Land-Systems

This terrain is much less dissected by erosion than the Hamilton-Branxholme terrain and, considering the dissecting potential of the streams, this may be admitted as evidence of relative age. Also, the Cobbobboonee terrain does not have the deep kaolinitic weathering that is a feature of the Hamilton basaltic terrain, and this also may be admitted as evidence of a later date for the extrusion of the Cobbobboonee basalt than for the Hamilton basalt.

There is positive dating for the basalt at one locality, Portland, within these land-systems (Boutakoff 1963). There, the basalt overlies the Maretimo Member (Upper Pliocene) and is younger than the Werrikoo Member, the base of which has been considered by Gill as the base of the Pleistocene (Gill 1957b, 1961). The basalt at Portland, therefore, was extruded at about the time of the Plio-Pleistocene boundary.

Further evidence of the age of the basalt is the nature of the soils and relic formations, the chief of which are the krasnozem variants, the ortstein, and the buckshot-bearing soils.

The krasnozem variants at Portland, which Boutakoff (1963, p. 30) refers to as a product of 'lateritization' are developed on fresh basalt but, at Hamilton, they are developed only on the deep kaolinitic zone and not on fresh basalt on dissected slopes. One of us (E.D.G.), who considers that in Victoria krasnozems are commonly palaeosols formed at about the time of the Plio-Pleistocene boundary, regards these facts as evidence that the basalt of the Hamilton land-system was extruded long before that time and that the basalt of the Cobbobboonee land-system was extruded at about that time. This agrees with geological evidence. The other author (F.R.G.), however, thinks that in Victoria krasnozems can be developed under existing climates where the leaching potential is high. Thus, at Portland, the krasnozems may have developed relatively recently under climates similar to that of the present, whereas, at Hamilton the much lower leaching potential (Hallsworth 1952) precludes their development now on fresh basalt.

In water-logged conditions, with abundant organic matter, iron-oxide may be mobilized and then concentrated in numerous loci to form pisolites and, eventually, a massive nodular horizon of ironstone known as 'ortstein' (Hallsworth and Costin 1954). These authors consider that, on basalt, ortstein indicates cold and wet conditions in poorly-drained areas; they postulate an early-Pleistocene or mid-Pleistocene age for examples on basalt in New South Wales. The presence of such material in perched positions on the Cobbobboonee land-system agrees with the other evidence of an early Pleistocene age for the Cobbobboonee basalt.

The buckshot-bearing soils may have been developed under similar conditions and, therefore, perhaps at a similar time to those on the dissected basalt of the Hamilton land-system and to those widely found in the Dunkeld land-system.

Dunkeld Land-System

The dissection of the basalt of the Dunkeld land-system is much less than in the previous two land-systems, neither does it have their kaolinitic zone nor ortstein. On the other hand, there has been differentiation of the soil profile and development of buskshot to a more marked degree than in the soils of succeeding land-systems. Consequently, it seems that the basalt was extruded later than the Hamilton and Cobbobboonee basalts but earlier than the basalts of the other three land-systems.

Stratigraphy indicates the relative age of the basalts in some places. At Tarrington, e.g., the Dunkeld basalt occupies a valley in the Hamilton basalt.

Two pedological approaches are useful here, namely the content of magnetic iron oxide, and the nature of the soil fabric.

One of us (E.D.G.) has worked out a means of dating basaltic tuffs. Where the factors of parent material, climate, and slope are equated by studying soils on low slopes of basaltic tuff in the one general area, the differences in the accumulation of gamma iron oxide are then a function of time. The series can be supported in their relative dating by the degree of profile development and the amount of dissection. Absolute dating is available by the radio-carbon method for some of the series. The youngest tuffs develop dust-size magnetic iron oxide, those of greater age develop micro-pisolites up to about 2 mm in diameter, while the next stage (10,000 to 12,000 years old) develops a full solodic soil profile with pea-sized buckshot gravel. If this type of relative dating can be extended to the basalts, then the dominant soils on the basalts of the Dunkeld, Strathkellar, Girringurrup, and Eccles land-systems are in that order of decreasing age.

Butler (1959) considers that the degree of organization of the soil fabric is controlled by the length of time for which a soil has been subject to weathering, and hence can indicate the 'K' cycle to which that soil belongs, within a limited area. In general, the greater degree of fabric organization is associated with soils of earlier K cycles. The dominant soils on the basalts of the Dunkeld, Strathkellar, Girringurrup, and Eccles land-systems have decreasing degree of organization of soil fabric in that order, supporting the conclusions from the approach using magnetic iron